

# THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 19

APRIL, 1934

No. 4

## THE MEASUREMENT OF FLOW-STRUCTURES

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### ABSTRACT

The problem of measuring and representing the orientation of biaxial minerals in rocks is considered. Orientation diagrams of feldspar and augite in a lava are presented. The feldspar shows a constant orientation pattern throughout the flow examined.

### INTRODUCTION

In a previous paper<sup>1</sup> the writer discussed the problem of measuring and representing the orientations of uniaxial minerals in rocks. It was pointed out that a more precise optical determination of the orientation of the crystal lattice is possible in the case of biaxial minerals. Three crystal classes only are of importance in this connection, the holohedral classes of the orthorhombic, monoclinic and triclinic systems.

In measurement with the universal stage the orientation of at least two of the axes of the optical indicatrix may be determined directly and the third can then be obtained graphically. Thus it is always possible to fix the orientation of the indicatrix. In the case of the orthorhombic system this also fixes the orientation of the crystallographic axes. Not so in the case of the monoclinic holohedral class, here two possible orientations of the crystallographic axes may correspond to one recognizable orientation of the indicatrix, and in the holohedral class of the triclinic system there are even four possible crystal orientations for each determined orientation of the indicatrix. If dispersion could be recognized in observations of this kind it might be an aid in establishing the situation of the crystallographic axes. As it is one must resort to the measurement of morphologic features, cleavage, crystal boundaries, twinning. If a single known crystal direction can be established and the orientation of the principal optical directions has been determined, the problem of fixing the crystal axes is solved for the classes here considered.

<sup>1</sup> "Pressure-shadows" and the measurement of the orientation of minerals in rocks, *Am. Mineral.*, **16**, pp. 55-70, 1931.

Schmidt<sup>2</sup> has discussed the representation of orientations of biaxial minerals. He selected some two of the principal optical directions and drew separate orientation diagrams for each. This procedure is satisfactory in the case of orthorhombic minerals but may obscure the results if used for monoclinic or triclinic minerals.

Let us suppose that all the  $c$  axes of the hornblende in a certain rock are oriented nearly parallel to a certain direction, and that also the  $b$  axes are nearly parallel. Let us further suppose that orientations measurements are represented by plotting optical directions. Then there will be two maxima for  $X$  and two maxima for  $Z$  but both pairs of maxima will correspond to a common maximum in the orientation of the  $c$  axes.

In triclinic minerals there also correspond several possible orientations of  $X$ ,  $Y$ , and  $Z$  to a given orientation of certain crystallographic directions. The case of the plagioclase feldspars is of particular interest. Suppose the feldspars in a certain rock to be oriented with the  $c$  axes nearly vertical and the (010) faces about parallel. To such an orientation there correspond four positions of the indicatrix. If measurements on such a rock were shown in diagrams for any pair of  $X$ ,  $Y$ , and  $Z$ , there would correspond four maxima of each of these to the single maximum that would be obtained by plotting the  $c$  axes or other suitable crystal elements. In this way the plotting of optical directions to represent the orientation of monoclinic or triclinic minerals may fail entirely to show the characteristic features of orientation.

So far studies in petrotectonics<sup>3</sup> have dealt largely with uniaxial minerals and such biaxial minerals, micas, as conveniently could be treated in a similar fashion. The purpose of this paper is two-fold, to treat an example of the orientation of biaxial minerals and to establish a type case of measured orientation due entirely to magmatic flow.

#### MATERIAL

The latite of Tuolumne Table Mountain, California, was selected for study. Both the geology and petrography of this flow are discussed in numerous publications of the U. S. Geological Survey. The most detailed description is given by Ransome.<sup>4</sup>

<sup>2</sup> Schmidt, W., Zur Regelung zweiachsiger Mineralien in kristallinen Schiefern, *Neues Jahrb.*, Beilb. **57A**, pp. 203-222, 1928.

<sup>3</sup> Knopf, E. B., Petrotectonics, *Am. J. Sci.*, **25**, pp. 433-470, 1933.

<sup>4</sup> Ransome, F. L., Some lava flows of the western slope of the Sierra Nevada, California, *Bull.* **89**, U.S.G.S., 1898.



Specimens, oriented in the field, were collected at six points along a fifteen-mile section of the middle course of the flow. Two or more thin sections of each were prepared affording a sufficient number of feldspar phenocrysts for statistical treatment.

The rock differs little from place to place, a fact also attested by earlier observers. The feldspar phenocrysts vary greatly in size, a few attaining maximum dimensions of half an inch or more. They are mostly euhedral tabular to (010). Other prominent forms are (001), (110) and ( $1\bar{1}0$ ). All crystals show many times repeated

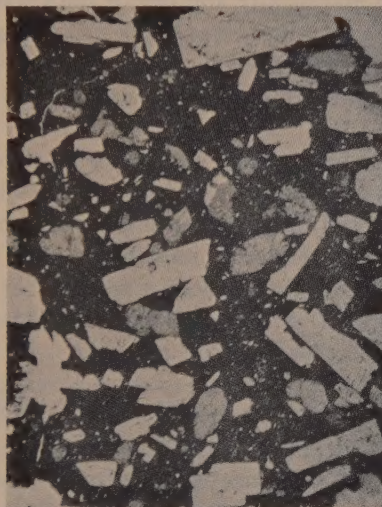


FIG. 1. Thin section of latite about 2 miles east of Vallecito, Big Trees Quadrangle, California. This section served for part of the measurements used in figures 2, 7 and 8.  $\times 2.4$ .

oscillatory zoning, but the range of composition is exceedingly narrow. Numerous determinations indicate that the feldspar throughout is a labradorite of about 52–53% An. This agrees well with the statement of Ransome that the composition is  $Ab_3An_4$  or  $Ab_1An_1$ .

The flow structure of the rock is not particularly conspicuous (fig. 1) but measurement showed it to be so uniform that only a selection of the results, representing however the entire length of the flow examined, will be reported here.

## METHOD

Most of the feldspar phenocrysts show albite, Carlsbad and La Roc Tourné twinning. Pericline twinning was observed occasionally. All four parts of a feldspar crystal twinned according to these three principal laws have two directions in common, the  $c$  axis and the normal to (010). Accordingly these two directions were chosen for representation in the diagrams.

The (010) poles can sometimes be fixed by direct observation. The  $c$  axes must be obtained indirectly. These directions are most easily determined graphically and one or both were so determined for each feldspar crystal measured. This was a most laborious task. It was facilitated somewhat by using a ground glass fitted with divided circle mounted to rotate over a Wulff net as suggested by Schmidt.<sup>5</sup>

It is desirable to plot a large number of poles for each diagram. To this end it was necessary to combine the observations from several thin sections of the same specimen for some of the diagrams, though a few of the larger sections afforded over a hundred measurements each. Where the sections were not cut parallel this involved another operation, the rotation of the plane of projection, carried out separately for each pole plotted.

All of the diagrams in this paper are on a vertical plane and the upward direction is at the top of the figure in each case. The letter S on each diagram denotes south. This fully fixes the orientation. No attempt is made to relate the results to direction of flow or other external vectors, except gravity, concerning the direction of which there might be some doubt. The legend adopted is the same for all diagrams and one convenient for the results obtained. The greatest concentration of poles observed was about 6 or 7% of the total within one per cent of the area.

## RESULTS

Figure 2 shows the orientation diagram of (010) poles in a specimen at the head of the section examined. Figures 3 and 4 show patterns for (010) poles and  $c$  axes in a specimen about 10 miles downstream. Figure 5 shows the pattern of (010) poles at the lowest point examined. Figure 6 shows the distribution of poles which form the basis for figure 5.

<sup>5</sup> *Op. cit.*, p. 205.

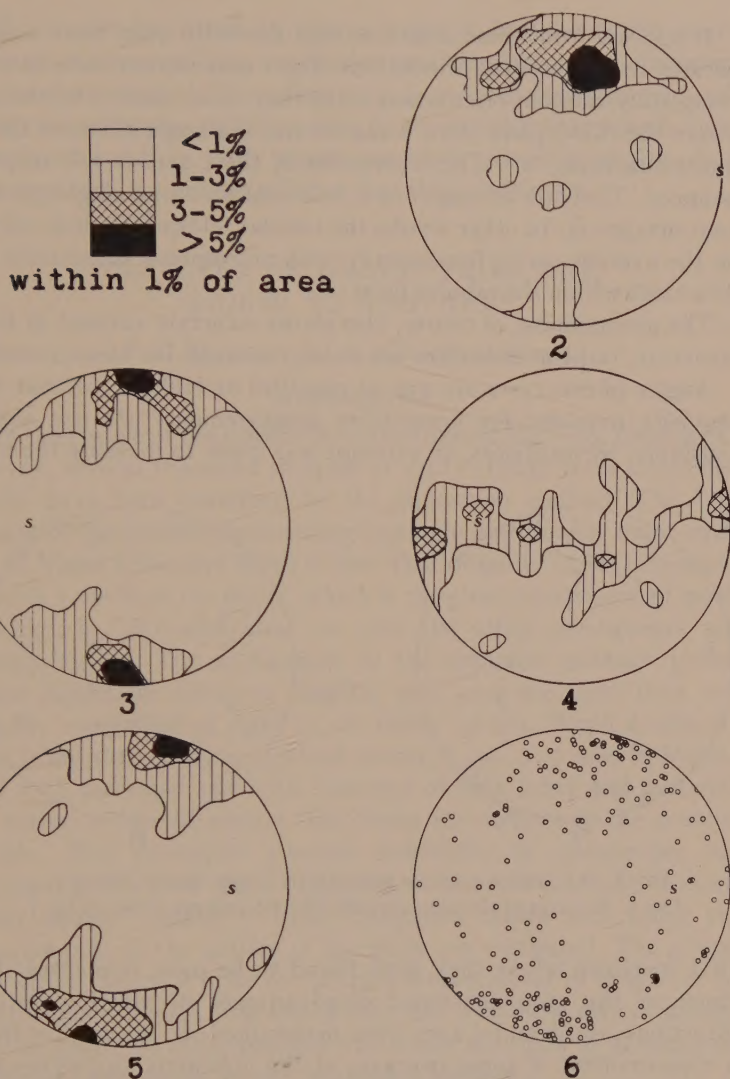


FIG. 2. Orientation diagram of (010) poles of labradorite in latite about 2 miles east of Vallecito, Big Trees Quadrangle, California. 224 poles plotted.

FIG. 3. Orientation diagram of (010) poles of labradorite in latite at railroad cut near Rawhide, Sonora Quadrangle. 99 poles plotted.

FIG. 4. Orientation diagram of *c* axes corresponding to fig. 3.

FIG. 5. Orientation diagram of (010) poles of labradorite in latite near Mountain Pass, Sonora Quadrangle. 207 poles plotted.

FIG. 6. (010) poles of labradorite corresponding to fig. 5.



It appears from these diagrams that the (010) poles have a sub-parallel nearly vertical orientation. The  $c$  axes cannot then have a completely random orientation since they must show a minimum where the (010) poles show a maximum, the angle between these directions, being  $90^\circ$ . The orientation of the  $c$  axes is not so pronounced. They are arranged in a belt containing no single prominent maximum. In other words, the tabular feldspar crystals seem, on the average, to lie horizontally with no common orientation of directions within the tabular faces.

The groundmass, of course, also shows a certain amount of flow structure, but the microlites are much too small for measurement.

Augite phenocrysts are not so plentiful as feldspar so that the requisite numbers for orientation measurements are not easily available. Nevertheless, an attempt was made to measure them in

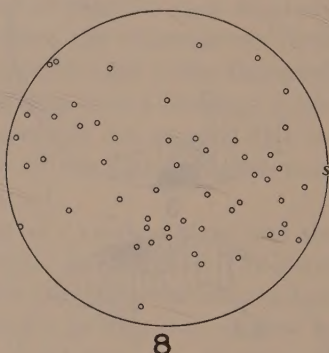
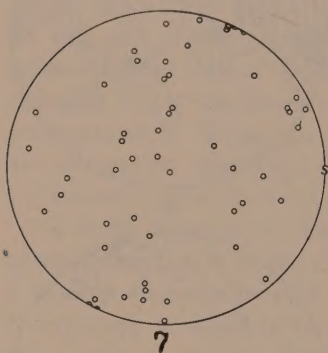


FIG. 7. 53  $b$  axes of augite in latite about 2 miles east of Vallecito.

FIG. 8. 53  $c$  axes of the same crystals whose  $b$  axes are shown in fig. 7.

that specimen where they were found to be most numerous. Because of the aforementioned disadvantages of plotting optical directions, the  $b$  and  $c$  axes were determined for the augites from a measurement of some two axes of the indicatrix and either the (100) twinning plane or the (110) cleavage or both. The forms (100), (010) and (110) could be observed on most of the short prismatic crystals. Some of the augite is intergrown with orthorhombic pyroxene and some is corroded or in aggregates. This was not included in the observations. Only single, mostly euhedral, crystals were measured. They too are very uniform,  $2V=47-50^\circ$  and  $Z \wedge c=43^\circ$ .

The results are shown in figures 7 and 8. Because of the small number of observations, contouring and shading of the diagrams were not attempted. The orientation is not nearly so pronounced as for the feldspars, but the *c* axes do seem to fall very largely in a horizontal band. In other words, the short prismatic augite crystals tend to be roughly parallel to the tabular feldspars.

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## TRANSFER OF GRAINS FROM ONE LIQUID TO ANOTHER\*

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### INTRODUCTION

In the course of the potash investigations of the U. S. Geological Survey, several thousand samples of drill cuttings from saline deposits have been examined by the immersion method. The first mount of the powder representing a sample is ordinarily made with an oil whose refractive index is near that of halite (1.544), because in such a medium the halite, which is the chief constituent of most samples, is "flattened out," so that the other constituents are clearly visible. The appearance of the common minerals under these conditions becomes familiar with practice, and they are usually recognized at sight in the initial mount. When a mineral that is not thus easily recognized occurs, it can, as a rule, be identified with certainty and with economy of both labor and material by means of the procedure that forms the subject of the present article. This procedure consists essentially of transferring individual grains from the initial immersion medium to one or more other liquids—usually to other immersion media with whose refractive indices the indices of the grain are compared. The grains are washed in xylol prior to accurate measurement of indices or to microchemical tests. It is hoped that this technique may occasionally be useful to other persons who study mixtures of minerals or artificial compounds by the immersion method.

### INSTRUMENTS USED

All of the instruments depicted in Fig. 1 may be employed in transferring grains, and they will be considered here with reference

\* Published by permission of the Director, U. S. Geological Survey. The author is indebted to R. K. Bailey, A. H. Koschmann, J. C. Reed, and A. C. Spencer for friendly criticism and advice.



to that purpose only, though some of them are also suitable for handling liquids in microchemical operations.

The instruments are designed for use under the microscope, and each is most comfortably held like a teaspoon in the fingers, which rest on the edge of the stage. As the inclination of the handle is then about  $30^\circ$ , the flat sole which terminates each of the instruments except the mounted needle is inclined  $30^\circ$  to the axis of the handle, so that it can be held essentially parallel to the stage when in use. The tip of each tool is placed near the axis, where it is easily guided and does not touch the table when the tool is laid down.

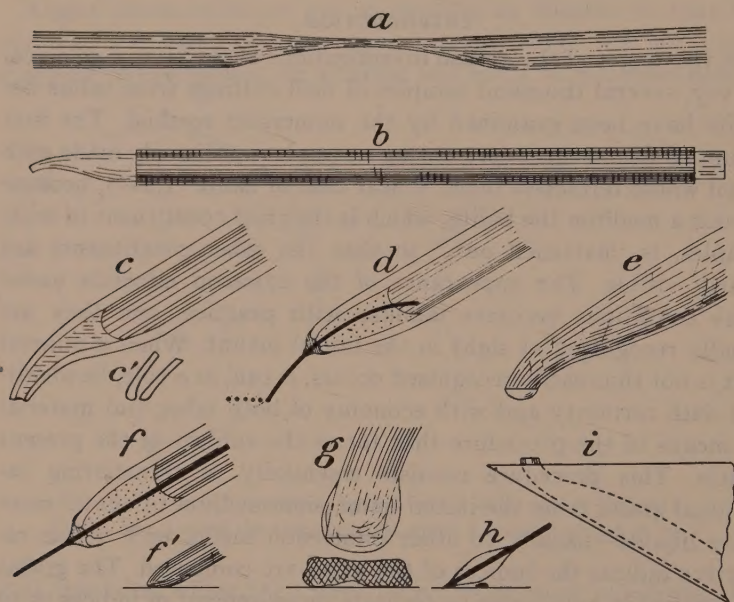


FIG. 1. *a*, Tube drawn out after heating unsymmetrically,  $\times 2/3$ ; *b*, Pipette with rubber sleeve,  $\times 2/3$ ; *c*, Section of "droplet-maker,"  $\times 4/3$ ; *c'*, Tip of "drinker,"  $\times 4/3$ ; *d*, Section to illustrate grain-lifter and crotchet; dotted lines represent eye of crotchet holding a lens of liquid; stippling represents hard balsam and darker shading "liquid solder"; *e*, Truncated rod, with charge of liquid on sole,  $\times 4/3$ ; *f*, Mounted needle,  $\times 4/3$ ; *f'*, Tip of same,  $\times 10$ ; *g*, Foot of grain-lifter, charged with soft balsam and poised over a grain,  $\times 50$ ; *h*, Needle dipped in balsam,  $\times 5$ ; *i*, Tip-gauge in use,  $\times 2/3$ .

Two pipettes (Figs. 1-*a* to 1-*c'*) may be made from a piece of glass tubing 25 mm. long and between 6 and 8 mm. in diameter, with walls at least 1 mm. thick. The tube is rotated in the fingers



while the middle of it is heated in a Bunsen flame until thoroughly soft. The rotation is then arrested, the heating continued for a few seconds longer, the tube withdrawn, and its ends pulled straight away from each other. The drawn-out portion, having been softened more on the under than the upper side, will have an asymmetric profile, of the character shown in Fig. 1-*a* but longer and more slender.

The two halves are separated, and one of them is fashioned as follows: The position of the sole is chosen at a point where the diameter is about  $1\frac{1}{2}$  mm. The knee is formed by gently heating the glass until it softens and bends under its own weight; the superfluous glass is then broken away on a scratch made with a file near the destined position of the sole. The sole is ground free-hand on fine sand-paper, at an angle of  $30^\circ$  with the axis, which is checked with a simple gauge made by folding an equilateral triangle of thin cardboard on a medial line (Fig. 1-*i*). The completed instrument is shown in Figs. 1-*b* and 1-*c*. The other half of the tube is made into a second pipette, which is like the first except that the diameter of the orifice is reduced to about  $\frac{1}{2}$  mm., by cautiously heating it before the sole is ground (Fig. 1-*c'*). The pipette with the larger orifice will be distinguished as the "droplet-maker,"<sup>1</sup> the small-mouthed one as the "drinker," because of the purposes for which they are to be used.

The form of pipette thus made is believed to be somewhat novel in form and mode of use. It is charged (Fig. 1-*c*) by capillary force when the tip is immersed in a liquid; the barrel should be inclined at least  $30^\circ$  while this is done. If the orifice is then brought in contact with a clean slide and raised, a droplet of the liquid will be left on the glass; and by repeated contacts a series of droplets, each a very little smaller than the preceding, may be deposited until the pipette is nearly empty. Neither suction nor blowing is employed; the pipette is charged by contact with the liquid and discharged by contact with the slide, and it may appropriately be called a *contact pipette*. It is convenient for holding xylol, which is frequently used in the procedure to be described, because it yields many droplets from a single charge.

The tool employed for picking up grains will be called the grain-lifter (Figs. 1-*d* and 1-*g*). Its handle is made by drawing out a tube

<sup>1</sup> "Droplet" seems a better term than "drop" for a bead of liquid too small to be formed by dropping from any pipette that is commonly used.

as in Fig. 1-*a*, cutting away the slender part, and fire-polishing the orifice. The tip is a short piece of moderately stiff wire. This may be made by annealing a small needle and cutting off the point; but steel "music wire" is more convenient though not always readily obtained in the small gauges required. A No. 10 or 12 needle, or No. 2 "music wire," which is about 0.27 mm. thick, is suitable for seizing most grains; but lifters with larger and smaller tips may occasionally be useful. To join the tip and handle, a few fragments of cooked balsam are dropped into the tube and melted in its taper end, the wire is inserted, and the balsam allowed to set. The wire is then bent to the proper curve and cut off about 5 mm. from the handle, and a sole is ground on its end with a carborundum whetstone. The wire is held with great tenacity by the balsam, and lateral play at the joint may be prevented by covering it with "liquid solder" or a clear cellulose cement.

The droplet of oil in which a captured grain is re-immersed for comparison of indices can be deposited from the rod attached to the usual type of oil-bottle, but its volume can be better controlled if this rod is used for charging a crotchet<sup>2</sup> (Fig. 1-*d*) or a truncated rod (Fig. 1-*e*), with which the oil is placed on the slide. The construction and properties of these instruments may be worth stating even if they are dispensed with in the procedure here described.

The eye of the crotchet has the form of a screw-eye with the joint slightly open instead of being closed as in a true loop. The crotchet used for the present purpose should have an inner diameter between 1 mm. and 1.5 mm., the gap at the joint should be about 0.3 mm. wide, and the wire of which it is made should have a diameter of about 0.35 mm. (26 or 28 gauge B. & S.). The crotchet is fashioned by looping the wire around a stout darning needle, pulling it snug, cutting it inside the crossing, and bending up the shank. Various metals may be used. A crotchet of brass or "nickel silver" wire should be cemented into the handle as in Fig. 1-*d*; nickel-chromium wire may be either cemented or fused in, care being taken to heat as little of it as possible; platinum or platinum-iridium—which is better because stiffer—should be fused in.

The crotchet is charged by bringing it in contact with the liquid

<sup>2</sup> "Crotchet" is English for "Häkchen," the word used by H. Behrens (*Anleitung zur mikrochemischen Analyse*, 1895, p. 20) to designate an instrument not figured nor fully described but presumably the same in essentials as the one described here.



hanging at the end of the rod from the oil-bottle and drawing it aside. It will then hold a convex lens of liquid. When this lens touches a slide, it instantly breaks, and nearly all the liquid is deposited. When a loop is similarly handled, the lens is not broken, and much of the liquid is retained. The crotchet, therefore, wastes less liquid and is more easily cleaned than a loop. It is sufficiently freed from oil if gently wiped and twice rinsed with xylol.

The truncated rod, whose sole should be about 2.5 mm. broad, is made from soft Pyrex rodding in the same manner as the pipette, but its sole is fire-polished. It is charged and discharged like the crotchet, but retains more of the liquid. The oil remaining on the tip can be quickly and almost completely removed by wiping, but the glass is electrified by friction and attracts fibers, which may cause annoyance by being deposited with the oil.

A mounted needle for moving grains about is shown in Fig. 1-f. It is mounted like the grain-lifter, but the tubing from which the handle is made is rotated throughout the heating process, to get a symmetrical taper. The point of the needle, which should be a fine one, is rounded off (Fig. 1-f') so that it will not catch in scratches on the slides.

The handles of all the tools may be sheathed with rubber tubing (Fig. 1-b), but this is not advisable unless the handle is less than 7 mm. thick. The grain-lifter, crotchet, and needle may optionally be mounted in wooden handles. A neat handle can be made by cutting off both ends of a pen-holder; the metal tip is inserted in a hole made in the smaller end with a mounted coarse needle and the joint is covered with cement.

#### PROCEDURE

If the mount is covered, the cover-glass must of course be removed, which may be done either by pushing it aside with a needle, but the immersion medium is likely to be so much disturbed by this operation that it may not be possible to find the desired grain afterward. This trouble is avoided when covers are dispensed with, which may often be done without disadvantage. The grain, unless it is rather large, is first isolated, a space being cleared with the mounted needle and the grain drawn into it with the same tool.

The sole of a grain-lifter, whose diameter should be greater, or not much less, than that of the desired grain, must now be covered with a substance to which the grain will adhere while be-

ing lifted out of the oil but from which it can readily be freed. Soft balsam is the material that I first found to fulfill these requirements and that I have chiefly used. The form assumed by the balsam which adheres to a lifter whose tip has been dipped in it is shown in Fig. 1-g: much of it is under the sole, where it can readily be pressed against the upper surface of the grain, whereas that taken up by a needle (Fig. 1-h) pulls away from the point and is obviously less effective. A material that now seems preferable to balsam is vaseline. The use of vaseline was suggested to me by Mr. A. H. Koschmann of the U. S. Geological Survey, who experimented with it at the suggestion of Professor A. N. Winchell but did not obtain satisfactory results because he used a needle, necessarily carrying a relatively large quantity of vaseline, and because he did not hit upon a way to remove the vaseline from the captured grain. The grain-lifter need carry only a minute quantity of the grease, with which the sole is coated by dabbing it against a thin layer smeared on a slide. A third adhesive recently found effective is mucin, applied to the sole by lightly touching it to the tongue. This practise is rather uncleanly, and grains adhere a little less readily to mucin than to vaseline. Mucin, on the other hand, offers a definite advantage when a grain is to be picked out of a liquid that contains a large proportion of monochloronaphthalene or methylene iodide, for both of these compounds, which are constituents of many oils of high refractive index, dissolve vaseline and balsam with great rapidity but do not noticeably attack mucin.

The sole of the lifter, coated with the chosen adhesive, is immersed in the oil, poised close above the grain, brought gently down upon it, and rather quickly raised. After a little practise, one seldom fails to pick up at the first attempt any compact grain as much as 0.1 mm. in average diameter.

So much of the adhering oil can be drained from the grain, by bringing it a few times in contact with the dry part of the slide, that the remnant will not seriously vitiate a rough comparison of its refractive indices with the index of another oil, a droplet of which is placed on a slide by means of a crotchet or a rod. Usually the grain can be rubbed off the lifter into this oil, and picked out of it by means of the same lifter without putting more adhesive on the sole. One or two immersions thus made may suffice to identify the mineral, but if a more accurate determination of an index, or a microchemical test, is to be attempted, the grain, after being



drained as before, is washed in xylol, which may conveniently be done as follows:

A droplet of xylol is deposited on a clean slide by means of the pipette called the "droplet-maker." The tip of the grain-lifter, with the grain adhering to it, is immersed in the solvent and agitated until the grain is detached. The droplet of xylol, carrying oil and perhaps vaseline or balsam in solution, is then promptly taken up by means of the "drinker," which should be kept in contact with the slide while it is pushed into the droplet, moved around the grain, and drawn a little aside; it is then raised, and drained by touching the tip with absorbent paper.<sup>3</sup> The small quantity of xylol remaining on the slide soon evaporates, but an oily residue is usually visible after the first washing, and the washing should, as a rule, be repeated once or twice. Comparison of the refractive indices of the grain with that of xylol—about 1.494—is often useful, and if the mineral is thought to be one whose average index is near that figure it should be transferred immediately from the initial medium to xylol.

<sup>3</sup> "Disposable tissues," such as Kleenex, are useful for this purpose and for wiping liquids from instruments and slides.

# THE PETROGRAPHY OF SOME ANTARCTIC ROCKS\*

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## INTRODUCTION

There are 294 specimens in the Antarctic rock and mineral collections at the University of Michigan. Dr. Laurence M. Gould, geologist of the Byrd Antarctic Expedition, collected 103 of these specimens in South Victoria, Marie Byrd, and King Edward VII Lands. The remainder represents duplicate material collected by the National Antarctic, *Terra Nova*, Australasian Antarctic, Scottish Antarctic (1902-04), German South Polar (1901-03), French Antarctic (1903-05), and Swedish Antarctic Expeditions obtained in exchange by the University. Of the 178 specimens studied 152 thin sections have been examined qualitatively. Ninety-four thin sections have had their mineral constituents determined quantitatively by means of the recording micrometer. Fourteen new chemical analyses are added to the 158 previously recorded analyses of rocks from the Antarctic Continent and the Antarctic Archipelago. Analyses *f*, *i*, *m*, *q*, *s*, and *t* in Tables I and II have been previously recorded.

Gould (3) has published a map of that portion of the Queen Maud Mountains of South Victoria and Marie Byrd Lands which was surveyed by his party. Gourdon (4) has described petrographically specimens 7, 9, and 13, and Stillwell (8) has made a thorough study of specimens 18, 19, and 20 (Table III).

## GENERAL STATEMENTS

In many petrographical papers published in the United States and abroad the qualitative microscopic determinations of the minerals found in a thin section are accompanied by the standard mineral compositions which have been computed from the chemical analyses of the rock specimens. The standard mineral composition represents the norm of the rock which is the basis of the well-known C.I.P.W. classification of igneous rocks (1). Finlay (2) gives a brief description of this classification, and lists numerous

\* Part of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

This article is a preliminary paper on the geology and petrography of the Antarctic Continent which is in part completed and which will be published later in full.



examples of calculated analyses to aid the beginner in obtaining command of the formulated method of calculation. Johannsen (7) (pp. 83-99) has recently reviewed this chemical method for the classification of igneous rocks.

The quantitative determinations of the percentages of the actual mineral constituents present in thin sections may readily be calculated by the use of the improved Wentworth recording micrometer described by Hunt (6). The quantitative classification of Johannsen (7) (pp. 140-158) has been used in selecting the names of the igneous rock types. Although the C.I.P.W. system treats only of igneous rocks other types will also be considered in the following discussion in that the chemical-mineralogical calculations of sedimentary and metamorphic rocks will be compared with the data obtained with the recording micrometer.

#### ACCURACY OF THE MICROMETER METHOD

An aggregate distance of some 39,000 units was measured in traversing each thin section, an average of 15 times with the recording micrometer. The following are examples of the accuracy obtained by the use of the micrometer:

(1) The percentages of the mineral constituents of two thin sections of the same rock—a tonalite from Mount Betty, Queen Maud Mountains, South Victoria Land, Antarctica.

	(a)	(b)
Quartz	43.48	39.41
Oligoclase	40.88	42.61
Biotite	14.58	15.73
Muscovite	0.74	1.46
Magnetite	0.32	0.55
Other accessories	—	0.26
	<hr/> 100.00	<hr/> 100.00

(2) The percentages of the mineral constituents of two thin sections of the same rock—a diabase from Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica.

	(a)	(b)
Quartz	0.95	1.91
Micrographic intergrowth	7.86	7.13
Labradorite	50.37	49.65
Mafites	40.03	40.70
Iron "ores"	0.80	0.61
	<hr/> 100.01	<hr/> 100.00

(3) The percentages of the mineral constituents of one thin section taking two complete sets of readings—a biotite schist from midway between Stations 1 and 2, Queen Maud Mountains, South Victoria Land, Antarctica. The readings were made parallel to the schistosity.

	(a)	(b)
Quartz	19.74	19.38
Feldspar	0.70	0.75
Biotite	67.61	67.34
Muscovite	11.77	12.37
Auxillaries	0.18	0.18
	<hr/> 100.00	<hr/> 100.02

(4) The percentages of the mineral constituents of one thin section taking two complete sets of readings—a granite gneiss from Great Mackellar Island, Adelie Land, Antarctica.

	(a)	(b)
Quartz	26.47	26.63
Feldspar	62.58	63.37
Biotite, chlorite	5.90	5.84
Muscovite	2.68	2.44
Accessories	2.36	1.72
	<hr/> 99.99	<hr/> 100.00

(5) Comparison of the mineral percentages of one thin section as determined with the recording micrometer with the data obtained from another thin section of the same rock as determined by the Rosiwal method. A plagioclase-pyroxene gneiss from Madigan Nunatak, Adelie Land, Antarctica. [See Stillwell (8) (p. 129).]

	Stewart	Stillwell (Rosiwal)	Difference
Feldspar, quartz	49.01	42.50	6.51
Pyroxene	43.02	45.50	2.48
Hornblende, biotite	3.19	3.60	0.41
Iron "ores"	4.68	8.40	3.72
Apatite	0.11	—	0.11
	<hr/> 100.01	<hr/> 100.00	

#### CHEMICAL ANALYSES OF THE ROCKS

In Tables I and II are the chemical analyses of the rock specimens that have been examined quantitatively with the micrometer. From these 20 analyses the volumetric norms have been calculated for comparison with the quantitative microscopical data. Analyses *f*, *i*, *m*, *q*, *s*, and *t* have been previously recorded.



TABLE I. CHEMICAL ANALYSES OF ROCKS EXAMINED PETROGRAPHICALLY.

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>
SiO <sub>2</sub>	77.83	75.89	75.37	75.13	72.78	71.10	70.36
Al <sub>2</sub> O <sub>3</sub>	11.71	13.36	12.94	14.15	14.70	14.50	14.00
Fe <sub>2</sub> O <sub>3</sub>	0.11	0.89	0.06	0.07	0.27	0.31	0.77
FeO	1.24	0.18	1.48	0.89	1.18	3.10	3.32
MgO	tr	0.06	0.07	0.07	0.42	1.17	1.29
CaO	0.63	0.27	0.73	0.35	0.99	2.59	2.09
Na <sub>2</sub> O	3.11	4.78	3.23	4.07	3.01	3.25	2.98
K <sub>2</sub> O	4.19	3.71	5.13	4.27	5.77	4.02	3.05
H <sub>2</sub> O	0.56	0.54	0.44	0.44	0.46	0.25	0.71
H <sub>2</sub> O—	0.09	0.11	0.07	0.10	0.04	—	0.06
TiO <sub>2</sub>	0.10	0.04	0.10	0.02	0.21	0.46	0.89
P <sub>2</sub> O <sub>5</sub>	0.06	0.08	0.02	0.09	0.20	0.03	0.21
MnO	0.02	0.01	0.02	0.02	0.03	n.d.	0.08
F	0.15	n.d.	0.15	0.15	n.d.	n.d.	n.d.
O=F	0.06	—	0.06	0.06	—	—	—
	99.74	99.92	99.75	99.76	100.06	100.78	99.81

	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>	<i>m</i>	<i>n</i>
SiO <sub>2</sub>	64.57	59.85	53.64	52.67	52.41	36.70	78.54
Al <sub>2</sub> O <sub>3</sub>	16.92	16.90	14.56	13.17	15.53	11.00	10.81
Fe <sub>2</sub> O <sub>3</sub>	1.30	1.92	1.81	0.74	1.79	14.21	0.35
FeO	2.14	5.22	8.12	6.75	6.64	12.24	1.42
MgO	1.71	3.12	6.14	11.81	8.03	7.55	0.80
CaO	4.09	6.63	10.39	12.01	10.74	11.90	0.73
Na <sub>2</sub> O	4.52	3.45	1.87	1.03	1.64	0.95	3.32
K <sub>2</sub> O	2.01	1.28	0.50	0.39	0.62	0.20	2.08
H <sub>2</sub> O	1.62	0.87	1.65	0.57	1.36	1.36	0.95
H <sub>2</sub> O—	0.13	—	0.41	0.25	0.65	—	0.09
TiO <sub>2</sub>	0.53	0.84	0.82	0.43	0.55	3.85	0.65
P <sub>2</sub> O <sub>5</sub>	0.17	0.06	0.15	0.12	0.07	n.d.	0.15
MnO	0.05	n.d.	0.17	0.17	0.14	n.d.	0.06
	99.76	100.14	100.23	100.11	100.17	99.98	99.95

- (a) Monzogranite (specimen 1). Rockefeller Mountains, King Edward VII Land, Antarctica. Ellestad, analyst.
- (b) Leucogranitic aplite (specimen 4). *Ibid.*
- (c) Porphyritic leucomonzogranite (specimen 2). *Ibid.*
- (d) Alaskite (specimen 5). Rockefeller Mountains, King Edward VII Land, Antarctica. Kameda, analyst.
- (e) Leucogranite (specimen 6). One half way between Stations 1 and 2, Queen Maud Mountains, South Victoria Land, Antarctica. Kameda, analyst.
- (f) Cranodiorite (specimen 7). Wandel Island, Antarctic Archipelago, Antarctica. Pisani, analyst.

- (g) Tonalite (specimen 3). Mount Betty, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (h) Granodiorite (specimen 8). Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (i) Tonalite (specimen 9). Wandel Island, Antarctic Archipelago, Antarctica. Pisani, analyst.
- (j) Diabase (specimen 10). Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica. Kameda, analyst.
- (k) Gabbro (specimen 12). Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (l) Melabasalt (specimen 11). Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (m) Melagabbro (specimen 13). Cape Tuxen, Graham Land, Antarctica. Pisani, analyst.
- (n) Arkose (specimen 14). Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.

TABLE II. CHEMICAL ANALYSES OF ROCKS EXAMINED PETROGRAPHICALLY.

	<i>o</i>	<i>p</i>	<i>q</i>	<i>r</i>	<i>s</i>	<i>t</i>
SiO <sub>2</sub>	69.89	69.76	67.10	64.51	50.62	48.74
Al <sub>2</sub> O <sub>3</sub>	13.14	15.15	14.87	16.87	11.43	13.64
Fe <sub>2</sub> O <sub>3</sub>	0.43	0.87	1.14	1.33	4.43	3.31
FeO	5.61	2.51	3.76	4.06	11.11	9.98
MgO	2.82	1.25	1.80	2.58	6.87	7.12
CaO	0.37	3.20	3.47	0.94	10.90	10.34
Na <sub>2</sub> O	1.81	3.53	2.56	1.35	1.75	1.96
K <sub>2</sub> O	3.21	2.42	3.50	5.17	0.24	0.83
H <sub>2</sub> O	1.31	0.59	0.68	1.75	0.62	1.95
H <sub>2</sub> O—	0.04	0.05	0.11	0.03	0.19	0.11
TiO <sub>2</sub>	0.68	0.38	0.68	0.82	1.42	1.26
P <sub>2</sub> O <sub>5</sub>	0.10	0.14	0.20	0.22	0.08	0.14
MnO	0.43	0.07	tr	0.07	0.28	0.35
CO <sub>2</sub>			nil			tr
SO <sub>3</sub>			nil		nil	nil
S						0.06
Cl			0.05		tr	
ZrO <sub>2</sub>						nil
Cr <sub>2</sub> O <sub>3</sub>						0.05
NiO, CoO			tr		0.03	0.01
CoO			nil		tr	tr
BaO						nil
Li <sub>2</sub> O			tr		tr	tr
O=Cl						0.01
O=S						0.02
	99.84	99.92	99.92	99.70	99.97	99.86

- (o) Biotite schist (specimen 15). Supporting Party Mountain, Queen Maud Mountains, Marie Byrd Land, Antarctica. Ellestad, analyst.
- (p) Oligoclase-biotite gneiss (specimen 16). O'Brien Peak, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (q) Granodioritic gneiss (specimen 18). Cape Denison, Adelie Land, Antarctica. Watson, analyst.
- (r) Muscovite-biotite schist (specimen 17). Southeast of Station 1, Queen Maud Mountains, South Victoria Land, Antarctica. Ellestad, analyst.
- (s) Plagioclase-pyroxene gneiss (pyroxene granulite) (specimen 19). Madigan Nunatak, Adelie Land, Antarctica. Hall, analyst.
- (t) Amphibolite (specimen 20). Cape Denison, Adelie Land, Antarctica. Hall, analyst.

#### CHEMICAL-MINERALOGICAL CALCULATIONS AND THE MODE

The authors of the C.I.P.W. classification (1) (pp. 147-152) state that the rocks of Classes I and II, rocks high in the standard minerals, have norms that show almost complete accord with the modes. Due to the presence of alferic minerals the norms and modes of rocks of Classes III and IV show less accord, although those of Class V again exhibit a rather close correspondence.

The following is a typical example of (1) norm of the rock, (2) the volumetric chemical-mineralogical determinations derived from the norm taking into consideration the specific gravities of the minerals, and (3) the data obtained with the recording micrometer. The rock is a leucogranite (specimen 6, chemical analysis *b*).

	(1)	(2)	(3)
Quartz	30.00	29.78	30.6
Orthoclase	34.47	35.56	45.4
Albite	25.15	25.26	} 16.5
Anorthite	4.17	3.97	
Corundum	1.94	1.29	2.6 (muscovite)
Hypersthene {	FeO · SiO <sub>2</sub> 1.58	} 2.04	} 4.8 (biotite)
	MgO · SiO <sub>2</sub> 1.10		
Ilmenite	0.46	0.26	} 0.1 (apatite, zircon)
Magnetite	0.46	0.24	
Apatite	0.34	0.28	
H <sub>2</sub> O	0.50	1.32	
	100.17	100.00	100.0

It will be seen that the percentages of the feldspars of the chemical-mineralogical and quantitative microscopical determinations are not in close agreement. This indicates that the rocks high in the standard minerals do not *always* have norms that show almost com-



plete accord with the modes. This variation is due to the fact that pure orthoclase is of rare occurrence in nature.

Harker (5) (pp. 245-246) makes the following statement:

"Orthoclase crystals contain an admixture of Ab (and An) up to a limit of about 28 *per cent*, and plagioclase crystals may contain Or up to about 12 *per cent*."

Inasmuch as the feldspars contain varying amounts of the K, Na, and Ca molecules they should be grouped in both the norm and the mode. When this is done the correspondence between the totals is rather striking. In like manner, due to the variability of the compositions of the alferic minerals they, too, should be grouped in both the norm and the mode.

In the above table the excess of  $\text{Al}_2\text{O}_3$  is calculated as corundum in the chemical-mineralogical determinations whereas this mineral is absent in the mode. It is practically impossible to calculate from the chemical composition accurate amounts of such minerals as muscovite and biotite, which frequently occur as important constituents in the rock. For example the muscovite present in specimen 15 (Table III), must be reported as feldspar although feldspar is really a minor constituent. If the rock contains a high percentage of Na- or K-minerals the entire amount of the Na and K are calculated as orthoclase or albite in the norm, instead of the Na- or K-mineral that actually occurs in the rock.

Table III shows the grouped chemical-mineralogical calculations and the correspondingly grouped quantitative microscopical determinations. An average of the mineral constituents of two thin sections was used in computing the data of specimens 3, 14, 15, 16, and 17. Under the term *mafites* in the chemical-mineralogical analyses the minerals considered include hypersthene, diopside, olivine, and iron "ores," while in the quantitative microscopical measurements the minerals actually present are hornblende, augite, biotite (chlorite), and the iron "ores." Under the heading *other constituents* the norm includes apatite, fluorite, and water. The microscopical determinations include auxillary minerals.

TABLE III. COMPARISONS OF THE GROUPED MINERALS OF VOLUMETRIC NORMS AND MODES.

	Quartz	Feldspars	Corundum	Mafites	Other Constituents
1.	41.54* 34.42**	53.17 59.54	1.01 —	1.80 5.48	2.49 0.62
2.	34.63 35.37	60.75 61.29	0.74 —	2.27 3.03	1.60 0.34
3.	33.88 41.445	54.98 41.745	1.46 —	7.29 15.630	2.37 0.130
4.	33.34 37.67	63.05 57.42	0.88 —	0.75 4.87	1.98 —
5.	33.16 32.44	61.39 61.14	1.77 —	1.48 4.06	2.22 2.32
6.	29.78 30.60	64.79 61.90	1.29 —	2.54 4.80	1.60 2.70
7.	27.26 37.86	65.48 53.84	— —	6.55 8.10	0.67 0.19
8.	18.82 23.67	69.90 67.22	0.14 —	6.20 9.11	4.92 —
9.	14.91 19.04	66.44 53.05	— —	16.24 27.32	2.42 0.59
10.	9.14 1.91	52.44 56.78	— —	32.12 41.31	6.29 —
11.	5.71 2.06	52.88 41.95	— —	34.92 55.98	6.07 —
12.	3.41 —	45.62 66.47	— —	47.18 33.54	2.79 —
13.	— —	41.46 40.88	— —	54.08 59.12	4.45 —

\* Volumetric chemical-mineralogical

\*\* Quantitative microscopical

TABLE III (Continued).

	Quartz	Feldspars	Corundum	Mafites	Other Constituents
14.	48.63 48.675	43.27 48.605	1.43 —	3.59 2.715	3.04 0.115
15.	30.64 33.97	47.93 41.29 <sup>a</sup>	5.31 —	11.01 23.53	5.11 0.21
16.	30.89 30.44	60.02 60.66	0.91 —	6.16 8.67	1.98 0.26
17.	30.90 50.11	51.71 1.47	0.13 —	13.69 42.03	3.83 6.41
18.	27.72 42.80	60.24 42.47	0.63 —	8.94 14.72	2.43
19.	1.21 25.53	49.54	— —	42.79 74.47	6.46
20.	7.26 49.01	43.69	— —	46.24 51.00	2.80

<sup>a</sup> Muscovite

1. Monzogranite. Rockefeller Mountains, King Edward VII Land, Antarctica.
2. Porphyritic leucomonzogranite. *Ibid.*
3. Tonalite. Mount Betty, Queen Maud Mountains, South Victoria Land, Antarctica.
4. Leucogranitic aplite. Rockefeller Mountains, King Edward VII Land, Antarctica.
5. Alaskite. *Ibid.*
6. Leucogranite. One half way between Stations 1 and 2, Queen Maud Mountains, South Victoria Land, Antarctica.
7. Granodiorite. Wandel Island, Antarctic Archipelago, Antarctica.
8. Granodiorite. Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica.
9. Tonalite. Wandel Island, Antarctic Archipelago, Antarctica.
10. Diabase. Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica.
11. Melabasalt. *Ibid.*
12. Gabbro. *Ibid.*
13. Melagabbro. Cape Tuxen, Graham Land, Antarctica.
14. Arkose. Mount Fridtjof Nansen, Queen Maud Mountains, South Victoria Land, Antarctica.



15. Biotite schist. Supporting Party Mountain, Queen Maud Mountains, Marie Byrd Land, Antarctica.
16. Oligoclase-biotite gneiss. O'Brien Peak, Queen Maud Mountains, South Victoria Land, Antarctica.
17. Muscovite-biotite schist. Southeast of Station 1, Queen Maud Mountains, South Victoria Land, Antarctica.
18. Granodiorite gneiss. Cape Denison, Adelie Land, Antarctica.
19. Plagioclase-pyroxene gneiss (pyroxene granulite). Madigan Nunatak, Adelie Land, Antarctica.
20. Amphibolite. Cape Denison, Adelie Land, Antarctica.

Considering the rocks as a whole, those igneous types that are acid in character exhibit good accord between the percentages of the *grouped minerals* of the volumetric norm and the *grouped minerals* of the mode. The acid rocks high in alferic minerals show groupings that have less agreement as noted in specimen 3, a tonalite. In this instance the rock contains over 15 per cent biotite. Aside from specimen 13, a melagabbro, the grouped minerals of the more basic rocks examined diabase, melabasalt, gabbro—show limited correspondence. Hence, we may conclude that of the rocks examined the majority high in alferic minerals exhibit little accord between the grouped minerals of the volumetric norms and modes. The one sediment, an arkose, shows good accord between the grouped minerals of the norm and mode. Metamorphic rocks show variability in accord between the groups, although the correspondence is closer in the more acid types, as may be noted in the oligoclase-biotite gneiss (specimen 16).

#### THE AB AN RATIO OF THE NORM AND THE MODE

Of considerable interest is the comparison of the Ab An ratios of the plagioclase determined microscopically and as calculated from the chemical composition of the igneous rock. In the acid rocks the correspondence between the Ab An ratio of the norm and the mode is very striking. In general it may be stated that the Ab of the norm is slightly higher than that of the mode in acid rocks, and tends to be the reverse in the more basic types studied. The following are a few typical examples:

Alaskite (specimen 5)	Diabase (specimen 10)
Mode $Ab_{97}An_3$	Mode $Ab_{50}An_{50}$
Norm $Ab_{100}An_0$	Norm $Ab_{35}An_{65}$
Monzogranite (specimen 1)	Melagabbro (specimen 13)
Mode $Ab_{93}An_7$	Mode $Ab_{46}An_{55}$
Norm $Ab_{95}An_5$	Norm $Ab_{25}An_{75}$

## RÉSUMÉ

Comparisons are made between the quantitative microscopical and volumetric chemical-mineralogical determinations of 20 rock specimens. Fourteen new chemical analyses of rocks from the Antarctic Continent are listed. It may be noted that the minerals of the volumetric norm and mode correspond in some cases, although in the majority of instances it is necessary to group such constituents, as feldspars, in order to obtain an agreement. In general, the Ab of the norm is slightly higher than that of the mode in acid rocks, and tends to be the reverse in the more basic types studied.

## ACKNOWLEDGMENTS

The author wishes to thank Dr. Laurence M. Gould, Professor A. Lacroix, and Sir Douglas Mawson for the opportunity of examining these rock specimens, and to acknowledge the friendly interest of Professors William H. Hobbs and Walter F. Hunt in the carrying on of this research. The author is indebted to Mr. Edward Mallinckrodt and Rear-Admiral Richard E. Byrd for financial assistance in having chemical analyses made of some of Dr. Gould's rocks at the Rockefeller Laboratory for Rock Analysis at the University of Minnesota.

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## THE "MICROHARDNESS" OF MINERALS COMPRISING THE MOHS SCALE

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For many years the estimation of the hardness of minerals has been based on the relative hardness of the minerals comprising the Mohs scale. It has been impossible to make hardness measurements with the Brinell or Rockwell tester on mineralogical samples because of the great forces involved, resulting in shattered crystals. In general, many other hardness testing methods are subject to this condition in a greater or lesser degree. It is true that obtaining an estimation of the hardness of the minerals in the Mohs scale, using one of the standard hardness testers, is mainly of academic interest. However, since this scale has had such widespread use and since the studies<sup>3</sup> of the hardness increments between adjacent steps have given, for the most part, discordant results, we have believed it pertinent to undertake a preliminary study, using the microcharacter,<sup>4</sup> a standard hardness tester designed for work on bearing metals.

The microcharacter (Fig. 1) consists essentially of a tiny diamond ground to the corner of a cube; this is sharp at a magnification of 2000 diameters. The diamond is mounted in such a manner as to operate (1) with the diagonal of the cube at 90 degrees to the test surface and (2) with the edge of the cube entering the test material at an angle of 35.25 degrees, as the latter is moved under the cutting point. A constant load is maintained by means of a

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small weight mounted on a lever-spring system regulated by a screw and indicated by a spirit level. This instrument gives a readily reproducible cut (called "microcut") whose width can be measured by means of a microscope having a filar micrometer eyepiece, and translated into a microhardness number. The microhardness is obtained by multiplying the reciprocal of the square of the width in microns by 10,000.

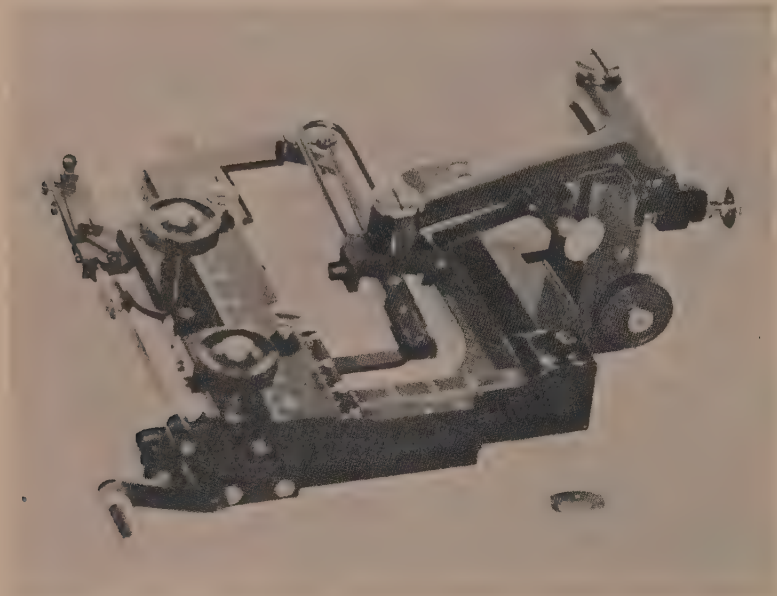


FIG. 1. The Microcharacter.

We are presenting a new method of determining the hardness of minerals which we believe to be capable of considerable accuracy. In competent hands, the interpretations obtained should be as accurate as those obtained with any other instrument, as there is absolutely no distortion. Cuts in different directions readily indicate whether (because of the angle of incision) any given cut has crystals torn from either or both edges. It has been found that cuts showing fractured edges may be discarded or readings may be taken at the narrow necks (Fig. 3-A). As would be expected the readings at the narrow neck are found to check very closely with the readings on uniform smooth cuts, made in other directions (Fig. 3-B).

We have undertaken to obtain microhardness values for each of the nine minerals from talc to corundum, using the microcharacter. Since the problem became of interest during the course of another investigation, this is not an exhaustive study, but, inasmuch as our results are fairly concurrent, we have tabulated our data herewith. These data were obtained as indicated upon microcuts made on different surfaces and crystal faces; parallel cuts being made in various directions and in opposite sense to assure uniformity and also for the purpose of checking microhardness values.

### I. TALC

The piece of talc studied was of the variety known as foliated. In order to study the talc it was necessary to embed it in a fusible alloy. The surface parallel to the principal plane of cleavage was cut first, in directions parallel but in sense opposite and second, in a similar fashion at right angles to the first group of cuts. Wide variations were found in the width of the microcut (Fig. 2-A) running from a width of 20 microns to almost 200 microns. These variations are interpreted as evidence that a number of different grains at different orientations had been cut through, at times perhaps chipping out entire groups of grains. This interpretation is made more probable when practically no reproducibility of the wide areas in the cut are found by making another cut parallel to, and in the same sense at a distance of two or three mms. from the first cut. A series of six paired cuts, in the same direction but opposite sense, gave average widths of 63.7, 60.6, 103.7, 69.4, 121.0 and 47.7 microns or an average of 77.8 microns. The microhardness corresponding to a width of 77.8 microns is defined as  $\frac{10,000}{(77.8)^2}$  or 1.6.

A series of four similarly placed cuts, on the same surface but at 45 degrees to the first series, gave average widths of 159.7, 75.5, 74.7, and 132.7 microns or an average width of 110.8, which is equivalent to a microhardness of 0.8. A series of two similarly placed cuts on the same surface, but at 90 degrees to the first series, yielded average widths of 104.2 and 102.8 microns, or an average width of 103.0 microns which gave a microhardness of 1.0. In order to test the changes of hardness, if any, which occurred on different surfaces parallel to the one first studied, the crystal was split and cuts made as before on the new plane. Confirmatory data in every respect were obtained. A series of four microcuts similar

to the first series gave average widths of 73.4, 100.4, 74.7 and 91.2 microns, or an average width of 84.9 microns which gave a calculated microhardness of 1.4. On the same surface but with microcuts at 90 degrees to the first series, a series of two microcuts gave average widths of 110.9 and 70.5, or an average width of 90.9 microns and a microhardness of 1.2. The average width of all the series on the surface parallel to the cleavage surface is 93.6 microns, which was equivalent to an average microhardness of 1.1.

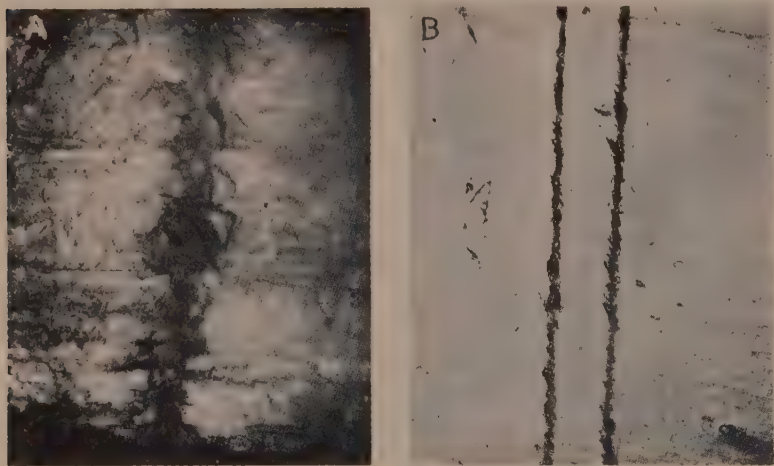


FIG. 2-A. *Talc*. (Original magnification approx. 53  $\times$ .) Microcut on surface parallel to cleavage surface. Average width of microcut, 93.6 microns. Average microhardness, 1.

FIG. 2-B. *Talc*. (Original magnification approx. 100  $\times$ .) Two microcuts in opposite sense on surface perpendicular to cleavage surface. Microcuts across trace of cleavage planes. Average width of microcut, 21.4 microns. Average microhardness, 21.5.

Sections were next cut vertically across the end and across one side of the specimen of talc. These vertical cross sections were mounted in a fusible alloy and microcuts were made in various directions, and always in pairs, one in opposite sense to the other. Here, surprisingly, microcuts (Fig. 2-B) were obtained about 20 microns wide and of a fair uniformity. A series of six microcuts across the trace of the cleavage plane gave average widths of 22.8, 19.9, 19.1, 22.8, 20.7 and 22.8 microns, or an average width of 21.4 microns from which a microhardness was computed of 21.5. A series of six microcuts along the trace of the cleavage plane pro-



duced average widths of 21.6, 19.9, 23.6, 24.8, 22.2 and 21.8 microns or an average width of 22.2 microns which gave a microhardness of 20.0.

It is to be noted that the average hardness of talc on the cleavage surface first studied is represented by a microhardness of approximately 1, while the average readings on the vertical cross sections gave a microhardness of 20 and 21.5.

## II. SELENITE

In selenite, the hardness on the clinopinacoid, pyramid and prism planes, i.e.,  $\{010\}$ ,  $\{111\}$ , and  $\{110\}$  planes respectively, were studied by means of microcuts in various directions. In general, cuts of two different variations were obtained, one quite regular and with fairly smooth edges, the other with one smooth edge and one irregular edge having had crystals torn out. The microhardness on the  $\{010\}$  and  $\{110\}$  planes were similar and gave an average width of cut which translated into microhardness varied from 10 to 13. A series of two microcuts in the clinopinacoid plane gave average widths of 28.8 and 31.4 microns, which yielded microhardnesses of 12.0 and 10.2 respectively. A series of seven cuts on the prism face produced average widths of 28.6, 30.0, 27.9, 31.1, 31.2, 28.6 and 28.1 microns, which resulted in microhardness determinations of 12.2, 11.1, 12.9, 10.5, 10.4, 12.2 and 12.8 respectively. The microcuts on the  $\{111\}$  plane showed a much greater hardness and gave values ranging from 25 to 57. A series of four cuts on the pyramid face resulted in average widths of 19.5, 18.1, 17.5 and 13.2 microns, from which microhardnesses were computed of 26.3, 29.5, 32.7 and 56.6 respectively. This last value may be in error inasmuch as the measurements were made on a crystal face which was marred by a large occlusion of an unknown nature.

## III. CALCITE

The cleavage faces or  $\{10\bar{1}1\}$  planes of the unit rhombohedron (Fig. 3-A) and also the crystal surfaces (Fig. 3-B) probably  $\{10\bar{1}0\}$  planes, were studied. Two types of microcuts were obtained; one regular with fine lines along one edge, and the other irregular, as if crystals had been displaced—usually along only one edge. The average microhardness of these cuts was approximately the same whether on cleavage or prism faces, and of a magnitude varying from 126 to 135. A series of three microcuts on the cleavage faces

gave average widths of 8.9, 8.7 and 8.6, which is equivalent to microhardnesses of 126, 132 and 135 respectively. A series of two cuts on the crystal face (probably prism face) yielded average widths of 8.8 and 8.8 microns which gave a microhardness of 129.

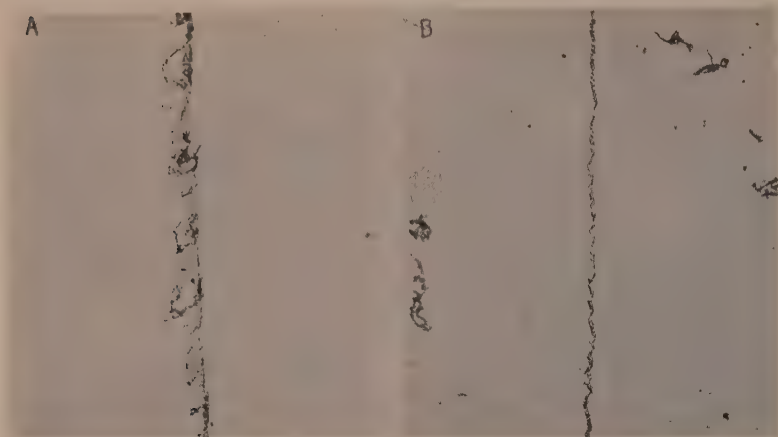


FIG. 3-A. *Calcite*. (Original magnification approx. 250  $\times$ .) Microcut in cleavage plane showing displaced crystals along one edge only. Average width of microcut, 8.7 microns. Average microhardness, 132.

FIG. 3-B. *Calcite*. (Original magnification approx. 250  $\times$ .) Microcut in crystal face showing regularity of edges. Average width of microcut, 8.8 microns. Average microhardness, 129.

#### IV. FLUORITE

The specimen of fluorite had only one surface suitable for examination, a  $\{111\}$  face. Values in the same direction but opposite sense showed a somewhat high degree of uniformity. A series of two microcuts gave average widths of 8.47 and 8.31 microns or an average width of 8.36 which is equivalent to a microhardness of 143.

#### V. APATITE

The microhardness of the  $\{0001\}$  and  $\{10\bar{1}1\}$  faces were studied. The microcuts were fairly smooth and uniform. A series of two cuts on the basal pinacoid plane gave average widths of 4.42 and 4.38 microns, or an average width of 4.40 microns and a microhardness of 517. A series of two cuts on the prism face yielded average widths of 4.95 and 4.95 microns and a microhardness of 408.

## VI. ORTHOCLASE

Only the  $\{001\}$  or basal pinacoid face was examined. The microcut was somewhat jagged. A single microcut averaged 3.19 microns in width and gave a calculated microhardness of 975.

## VII. QUARTZ

The rhombohedron  $\{10\bar{1}1\}$  and the unit prism  $\{10\bar{1}0\}$  faces were studied. Cuts were fairly smooth; the average width was 1.93 microns which gave a microhardness of 2700.

## VIII. TOPAZ

The single face studied here was probably a prism face. The cuts were jagged and the readings obtained were of a poor degree of uniformity. A single microcut gave an average width of 1.71 microns; a single microcut at 90 degrees to the first also resulted in an average width of 1.71 microns, or a microhardness of 3420.

## IX. CORUNDUM (variety Sapphire)

The face cut was the rhombohedron  $\{11\bar{2}0\}$  face. Two microcuts were clean and smooth and gave widths of 1.38 and 1.43 microns. The microhardnesses determined were 5270 and 4980.

A compilation of our average data is offered in Table I.

TABLE I. TABLE OF AVERAGES.

Mohs Scale	Width of cut in Microns	Microhardness
1. Talc	93.6	1
2. Selenite	90.3	11
3. Calcite	8.8	129
4. Fluorite	8.4	143
5. Apatite	5.5	517
6. Orthoclase	3.2	975
7. Quartz	1.9	2700
8. Topaz	1.7	3420
9. Corundum (variety Sapphire)	1.4	5300

When the data obtained are plotted as abscissae against the number of the appropriate mineral in Mohs scale a curve more or less logarithmic is obtained in which there is as much difference between the numbers 8 and 9 as there is between 6 and 7, and in

which the magnitudes of the microhardness for minerals 1 to 6 are small in comparison and of a more nearly uniform microhardness increment. The difference in microhardness between 7 and 8 is smaller than the differences between 6 and 7, and between 8 and 9. These results, however, are only approximate; specimens with different compositions might give other microhardness values.

It is suggested that the microcharacter may be applied to a more complete study of the hardness of minerals, particularly in regard to (1) the hardness changes produced by changes in composition; (2) the hardness changes produced in variously oriented crystals in an aggregate; or (3) the study of hardness with a view to the identification of the components of aggregates. We believe that this method of attack may suggest further opportunities for research on mineralogical problems.

#### ACKNOWLEDGMENT

The authors wish to express their indebtedness to Mr. C. H. Bierbaum at whose suggestion the estimation was undertaken. They also wish to thank Dr. Q. D. Singewald and Professor Harold L. Alling of the Geology Department of The University of Rochester for their technical advice.



# GRAPHITE IN PEGMATITE

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## INTRODUCTION

Graphite occurs disseminated through a small pegmatite lens which is intruded into limestone in the City Quarry, Lewiston, Maine. The mineral is not commonly reported in the pegmatites of Maine as there is but one paper known to the writer concerning graphite in Maine pegmatites (27). Landes (17*a*) lists graphite among the numerous minerals of the hydrothermal stage in the pegmatites of Maine. Bain (2) has indicated his belief in the same manner of origin for the Louisa, Quebec, graphite deposits. There are numerous other published accounts of the association of graphite with the contact zones between granitic and sedimentary rocks, or their metamorphosed equivalents. It is probable that the graphite of the City Quarry pegmatite represents a hydrothermal product.

## LOCATION

The city of Lewiston is located in the southwestern part of Maine, in Androscoggin County, on the left bank of the Androscoggin. It is 32 miles from Portland, and 34 miles from Augusta, the state capital. The quarry is located in the southern part of the city in a low hill known locally as "West Rose Hill." The quarry faces the Maine Central Railroad line to Brunswick, about one mile from the Lewiston Lower Station. The graphite-bearing pegmatite is in an abandoned quarry opening on the northwest slope of the hill along the road connecting the quarry with Lisbon street.

## GENERAL GEOLOGY

The bed rocks of the Lewiston region are predominantly metamorphic rocks, including quartz-mica schists, gneisses of regional and injection origin, slates, and crystalline limestones, all of which are intruded by granites, pegmatites and "trap" dikes. Field relations between the various rock types are obscured by glacial cover so that complete correlation is difficult. The crystalline limestones of the City Quarry are possibly pre-Ordovician in age and have been intruded by at least two pegmatites of different age, and by at least 16 basic dikes. (These limestones will be tentatively named

the *Lewiston* limestone.)<sup>1</sup> There are obvious differences noted in the intruding dikes, especially the melanocratic types, and it seems as though there were several periods of injection. Slight differences are also noted in the leucocratic dikes.

THE PEGMATITES.—The pegmatites of Maine, especially in the southwestern part of the state, have been described in numerous articles, and are of interest because of the large number of gem tourmalines, beryls, apatites, etc., and the great variety of rare minerals that they have yielded. The best known localities of these pegmatites are in Androscoggin and Oxford counties. Landes (17*a*) subdivides the pegmatites in general into acid, intermediate, and basic. He includes both simple and complex pegmatites under the acid division. The complex pegmatites show lithium, fluorine, beryllium, boron, phosphorus, *graphite*, rare earths, ore minerals and quartz vein phases. The writer accepts Landes's classification in general but because of the lack of the minerals typical of the complex pegmatites prefers to separate the acid pegmatites encountered here into tourmaline-free and tourmaline-bearing pegmatites. The graphite of the City Quarry occurs in a tourmaline-free pegmatite.

GRAPHITE-PEGMATITE LENS.—The graphite bearing pegmatite lens averages about two and one-half feet in thickness and about seven feet in width. It is exposed in limestones in an old working now filled with paving bricks. About ten feet of the limestone are exposed above the pegmatite lens. The limestone immediately around the graphite-bearing lens is badly weathered and is iron stained, but the limestone directly overlying the lens is fairly fresh. This limestone is massively bedded. The uppermost bed is about 26 inches thick and laminations in it are well-defined by the parallelism of biotite and phlogopite plates. Parallel vertical fractures set off this fresh limestone from the altered rocks on both sides. Below the 26 inch bed there is an 80 inch bed which shows slight parting into three distinct beds.

The calcite plates of the limestone are of large size and are intimately associated with mica. Numerous thin veinlets of milky quartz traverse the limestone, in places conforming with the bedding. Slender green hornblende needles one and one-half inches in length are included in these quartz veins. There are also scattered zones of pyrrhotite. The contact between the pegmatite lens and

<sup>1</sup> A paper discussing the general geology of the Lewiston quadrangle is in progress. Priority is sought for the name Lewiston limestone.

the overlying limestone is sharp. There are no noticeable garnet zones similar to those that occur in the larger quarry.

The pegmatite pinches out sharply to the right and left of the lens and can be traced as a thin pegmatite (or aplitic) vein to the right for more than eight feet. Where this veinlet thins down to less than an inch in thickness scattered grains of graphite are found. The graphite-bearing portion of this thin vein is cut by a series of milky quartz veins that contain schorl and garnet.

Another mass of pegmatite occurs in the pit below the graphite-bearing zone. It is apparently separated from the latter by several feet of limestone. Schorl is abundant in this lower pegmatite. The writer has been unable to find any direct connection between this tourmaline-bearing lower pegmatite and the graphite-bearing upper pegmatite. The lower one includes several large xenoliths of limestone which do not show any strong development of garnet or other contact minerals against the pegmatite contact.

PETROGRAPHY OF CITY QUARRY PEGMATITE.—The feldspar of the pegmatite is predominantly orthoclase, accompanied by small amounts of microcline and albite-oligoclase. Alteration of the feldspar to a kaolin-like product is pronounced. Quartz occurs in granulitic texture but there are also some cataclastic zones of small anhedral grains of the same mineral. The grains of these zones show wavy extinction. Zoisite is the most common secondary mineral developed in the pegmatite and shows the characteristic "ultra blue" interference colors. Several small, isolated patches of calcite enclosed by quartz occur in the pegmatite. A few subhedral forms of a pyroxene, whose extinction angle is near diopside, show frayed or ragged ends against both feldspars and quartz.

Graphite is distributed rather uniformly through all the pegmatite slides. (This feature is in keeping with the rather general distribution of graphite throughout the pegmatite lens.) There are several occurrences of graphite in feldspar cleavages, the graphite showing a greater affinity for altered feldspar than for fresh plates. Boundaries between anhedral quartz grains are crossed by the graphite, and the latter mineral completely encircles some quartz grains, especially where the latter occurs in cataclastic zones. The cleavages of the pyroxene are penetrated by graphite. Where associated with zoisite the graphite shows fairly sharp boundaries, although there are a few scattered grains of zoisite that include apophyses of graphite.

Graphite appears to be definitely later than the feldspar, quartz and pyrrhotite, and is contemporaneous with, or later than the zoisite.

THE LIMESTONE.—The limestone overlying the pegmatite shows very little graphite. No garnets were observed in the fresher limestone beds nor in the slides. The minerals accompanying the calcite of the limestone are pyrrhotite, actinolite, a small amount of diopside, zoisite, biotite, small amounts of muscovite, and brown mica probably phlogopite. The minerals are uniformly distributed through the limestone with the exception of the brown mica which is more abundant near the pegmatite contact.

Pyrrhotite apparently formed early. The actinolite encloses calcite in some portions of the slide and shows a thin zone of a highly birefringent mineral around the edges due to solution. Zoisite replaces both calcite and actinolite occurring in small equidimensional grains with distinct cleavage, low extinction angle and a low order of grayish blue interference colors.

Graphite, occurring in small amounts in the limestone, enters the cleavages of actinolite, mica and calcite.

#### GENERAL DISCUSSION OF GRAPHITE

A general discussion of graphite, its modes of occurrence and the theories of origin, is deemed advisable at this point.

MODES OF OCCURRENCE.—Graphite is widely disseminated geographically and geologically, occurring in many kinds of rocks, and apparently, originating in many different ways. A survey of the available articles from a voluminous literature on the subject suggests the following occurrences.

Miller (22) mentions two publications describing graphite in unmetamorphosed sediments. Weinschenk (34) states that graphite is rare in eruptive rocks but the mineral has been found in pegmatites. Lindgren cites Spencer's description of the occurrence of graphite in dikes near Franklin Furnace (20). The iron-bearing basalt of Ovifak, Greenland, carries graphite. Lee (18) has observed it in diabase intrusions in New Mexico. Holland (15) and Alling (1) describe occurrences in syenite and numerous other occurrences might be cited. The chief habitat, however, seems to be in altered limestones and schists where the graphite may have been formed either by volatile emanations from the magma or by metamorphism of the carbonaceous materials in the original rocks.



Numerous occurrences of this more general type are found in the literature and include areas where pegmatites intrude biotite-hornblende schists, amphibolites, quartzites, normal quartz schists, feldspar-quartz schists, garnetiferous-quartz schists, mica schists, limestones, marbles, etc. The occurrence of graphite associated with pegmatite intrusives in the above types of rocks is by no means restricted to the contact zones between the pegmatite and the host. Graphite may be disseminated through the intrusive or intruded rock.

In addition to the general occurrence in limestone, the outstanding type being the Ceylon vein type, Winchell (38) describes veins of graphite in faulted Paleozoic limestones of Ruby Range, Dillon, (Montana) area. Coleman (10) states "... a curious breccia of small gneiss fragments cemented by a black material like chert is found in loose black bands. In one such band of faulting and crushing small amounts of solid graphite—were observed." At Passau, Bavaria, graphite occurs in a crushed schistose rock.

Finally, two extremely rare types of occurrences have been cited, viz., graphite in meta-arkose in southern Adirondack area and finely disseminated through a zone of serpentinous dolomites of the Grenville district (37).

**MINERAL ASSOCIATES.**—The mineral associates of graphite are as varied as its modes of occurrence. In Ceylon graphite (5) is accompanied by apatite, rutile and pyrite; in the Adirondack contact zone deposits, by scapolite, pyroxene and vesuvianite; in the Adirondack schist deposits, by apatite, quartz, pyrite and muscovite; in the Buckingham and Grenville Township deposits (Quebec) (37), by apatite, pyrite, scapolite, biotite, titanite and wollastonite; at Dillon, Montana, it is accompanied by garnet; tourmaline is an associate in the Seward Peninsula (13) (23) deposits; quartz, biotite and microcline are cited by Winchell (38) in his study of the Dillon area; and in the Amherst township, Quebec, area, Wilson (36) listed pyroxene, quartz, titanite, wollastonite, diopside, orthoclase and calcite.

It will be noted that apatite and pyrite are associates in three of the above listed localities but since these may be regarded as flood minerals they cannot be used to determine the mode of origin except perhaps that the presence of apatite may be used to argue for changes in temperature due to the presence of mineralizers. The major suite of minerals is characteristically a contact

type and on the basis of mineral associates one might believe that pyrometasomatic origin is indicated.

THEORIES OF ORIGIN.—Clark (7) indicated that since many different methods have been suggested for the formation of graphite in various rocks, the older classification of organic and inorganic graphite no longer can be suitably adopted. He suggested a classification of graphite deposits, as, (a) Bedded deposits, (b) Disseminated deposits, (c) Veins or vein-like deposits, including fissure veins, contact deposits and pegmatite deposits, and (d) Deposits with native iron and in meteorites. The City Quarry graphite-bearing pegmatite would be regarded as a vein-like deposit, and would be chiefly a pegmatite type, and in part, contact type.

Alling (1) states that the pegmatite of the Ticonderoga township graphite deposits comes in direct contact with the limestone without affecting it in any appreciable way. He says:

The even distribution of the graphite through the crystalline limestone renders it probable that the carbon formed an original constituent of the limestone.

The conversion to graphite, the recrystallization of the limestone, the development of pyroxene, are the results of dynamic metamorphism, and to some extent to contact effects of neighboring masses of granite. Lindgren states that recrystallization of carbonaceous matter in metamorphosed sediments is due perhaps to intense regional metamorphism. Smith (27) regards the graphite in a Maine pegmatite as a conversion and concentration product of carbonaceous particles of sedimentary origin through the agency of heated vapors from the pegmatite magma. One might interpret Winchell's (38) discussion of the graphite of the Dillon, Montana, area as an expression of belief in organic origin for he rules out the carbide theory of graphite because carbides are extremely unstable in the presence of oxygen.

On the other side of the argument De Launay (11) after describing the xenoliths of crystalline limestone within the Alibert syenite states his conclusions as:

No known reaction will explain such a concentration. Thus the Siberian graphite seems to be of a new kind, of a deep-seated inorganic origin, probably of like origin with that of Ceylon.

De Launay's conclusion does not, however, agree with the organic theory advanced for the same deposits by Jaczewski (16) although the latter found support for his theory with Clark (7)

who held that the explanation was reasonable in view of the fact that graphitic schists or limestones might have been assimilated by the magma. Wilson (36) lists the order of crystallization of the minerals associated with the graphite as scapolite, wollastonite, orthoclase, titanite and diopside, then graphite and calcite which are contemporaneous, or with calcite a little later. On a later page in his article he lists three modes of origin: (a) recrystallization of carbonaceous material contained in the Grenville limestone; (b) derived from igneous rocks intruded into the limestone; and (c) from carbon dioxide of the limestone by reduction. Finally, Bain (2) states:

The graphite is plainly introduced material and is replacing earlier silicate minerals notably uralite and chlorite formed by alteration of pyroxenes of the skarn. Intimate relation of the alteration of the diopside and replacement of the alteration products seems to indicate that the same solutions are responsible for both processes. . . . since the graphite is found as a replacement of the alteration products of these silicates (lime silicates) the carbon could not possibly be derived from  $\text{CO}_2$  liberated by the silication of the carbonates original to the limestone but must have been a direct late stage magmatic emanation from the magma along with the silicic solutions producing the alteration of the skarn.

Thus the pendulum of paragenetic thought swings from one view of origin to the other and back again.

ORIGIN OF CITY QUARRY GRAPHITE.—Recrystallization of the limestone and the subsequent development of large calcite plates is due in part to regional metamorphism, and in part, to heat of the intruding pegmatite. The platy minerals, pyroboles and micas, occur in both limestone and pegmatite. There is pronounced parallelism of the mica plates especially near the contact. The immediate contact between the limestone and the pegmatite is sharp. There is no garnet zone, and no definite evidence of melting. These two features seem to indicate very little change in composition except the expulsion of  $\text{CO}_2$  from the limestone. "The proof that the additions are from the magma, and not from the substances leached from the wall rock is strongest when the inclusions of limestone inside an igneous rock are garnetized." (12) May one argue conversely then and say that the absence of the garnet zone is indicative of absorption of the limestone? The exchange of materials between the intruded and host rock is undoubtedly greatest on the cooler side—the host. The intrusive received from the host limestone,  $\text{CO}_2$ , calcium and magnesium, in exchange for silica which causes silication within the limestone and formed actinolite, zoisite,

diopside, etc. The CO<sub>2</sub>, freed from the calcium carbonate by the invading pegmatite formed graphite by deoxidation. The writer does not believe it was a part of the original pegmatite magma.

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## NOTES AND NEWS

### AN UNUSUAL OCCURRENCE OF ASBESTOS

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Asbestos associated with copper-bearing pyrite, galena, sphalerite, calcite, feldspar, quartz, and pyroxene was found in a banded fissure-vein deposit in the Snowy Range mine at Camp Albion, Boulder County, Colorado. The asbestos occurs in fibrous, sheet-like masses and in small, irregular aggregates with the minerals enumerated. The sheets are generally found in the middle of the vein and parallel to the banded structure. The irregular masses occur between the grains of the other minerals in the vein.

The banded appearance of the vein is due to successive depositions of pyroxene, sulphides, and asbestos in passing from the walls of the vein to the middle. Quartz has been deposited in only a few places and where present it occupies the middle of the vein instead of the asbestos. The vein varies from an inch to about a foot in width and occupies a fault zone in a coarse-grained monzonite. The vein is probably genetically associated with the monzonite.

The asbestos is light gray in color with a fusibility of three and colors the flame a brilliant yellow, due to its high sodium content. Some of the fibers are two inches in length. The extreme fineness of the fibers made its optical study difficult. The following data were obtained by using the immersion method. The highest extinction angle, measured from the long direction of the fibers to the x vibration direction, is about  $39^{\circ}$ . The mean index of refraction is about 1.630.

The asbestos was also examined in thin section. The section was ground at right angles to the long direction of the fibers. This permitted the examination of the cleavage. The cross-sections of the very fine fibers, when examined with a high power objective, showed in the majority of cases flatly oval shapes. A few angular cross-sections appeared to have the characteristic amphibole cleavage.

An analysis of the asbestos gave the following composition:

## ANALYSIS OF ASBESTOS

	<i>Per cent</i>	<i>Molecular Ratios</i>
SiO <sub>2</sub>	56.48.....	0.952
Al <sub>2</sub> O <sub>3</sub>	1.22.....	0.012
Fe <sub>2</sub> O <sub>3</sub>	8.38.....	0.053
FeO	2.67.....	0.037
CaO	2.70.....	0.048
MgO	17.40.....	0.437
Na <sub>2</sub> O	8.09.....	0.132
K <sub>2</sub> O	1.82.....	0.019
H <sub>2</sub> O (above 110°)	0.87	
TiO <sub>2</sub>	0.30	
	<hr/> 99.93	

The formula of the asbestos calculated from the analysis is approximately:  $3(\text{Na}, \text{K})_2\text{O} \cdot \text{CaO} \cdot 10(\text{Mg}, \text{Fe})\text{O} \cdot (\text{Fe}, \text{Al})_2\text{O}_3 \cdot 20\text{SiO}_2$ .

From the above data the asbestos is believed to be an alkali amphibole. In the analysis all the results were checked by parallel analyses except the determinations for the alkalis. Some difficulty was experienced in obtaining a proper fusion and extraction. The results of the best fusion are given.

The asbestos appears to have been deposited from solution. A careful examination of several specimens indicates that it is not an alteration product from any of the vein minerals. The common occurrence of the asbestos in the middle of the vein precludes the possibility of its being an alteration product from minerals in the wall rock. The occurrence of the asbestos in distinct sheets and sharply defined masses supports the idea of deposition from solution. The pyroxene was examined both in hand specimen and thin section for any gradation or alteration to the asbestos. Small patches of asbestos were found filling cavities between pyroxene grains, but the contact between the asbestos and pyroxene is sharp.

The other minerals occurring in the vein with the asbestos show several interesting features. The galena has both octahedral and cubical cleavages. The octahedral cleavage is much better developed than the cubical. The feldspar is a light gray soda-bearing orthoclase. It is biaxial positive. The maximum extinction angle measured from the trace of the basal cleavage is eight degrees.

The associated pyroxene, as determined from chemical and optical tests, is diopsidic aegirite and has the following optical properties: high relief; biaxial positive in character; X makes an angle of 17 degrees with *c* axis in the acute angle beta; pleochroism, X = green, Z = yellowish green. The pyroxene as it occurs in the vein

varies in color from medium gray to dull greenish gray. It had good cleavage and has a splintery fracture.

The pyrite, calcite, and quartz show no unusual features. The pyrite is massive, as is the quartz. The calcite occurs as separate masses or intimately mixed with the asbestos.

MOTTRAMITE OR PSITTACINITE—A QUESTION  
OF NOMENCLATURE<sup>1</sup>

WALDEMAR T. SCHALLER, *Washington, D.C.*

In the recent paper on psittacinite from Arizona,<sup>2</sup> I considered psittacinite the proper name for this mineral. Bannister, in his more recent paper on this mineral<sup>3</sup> did not accept my conclusion and stated that mottramite was more suitable. This disagreement led to correspondence with Bannister which has finally settled the question of priority.

I wrote him, in part, as follows:

I have been trying to check your conclusions regarding the nomenclature of mottramite and psittacinite, as expressed in your recent paper on The identity of mottramite and psittacinite with cupriferous descloizite. On page 385, you state: "Mottramite is the most suitable choice on all grounds. The use of the name psittacinite should be discontinued." So far as I can interpret the situation, it seems that psittacinite should be the name chosen.

It all depends on the question of priority. I was in error in stating on page 578 of our paper on Psittacinite from the Higgins mine, Bisbee, Arizona, that psittacinite was described by Genth in 1874. It should have been given as 1876, as you correctly do under VII on page 377 of your paper. The reference given on page 791 of Dana's *System of Mineralogy* is misleading.

"However, it seems to me that Genth's name still has priority. The question of priority, I think we will all agree, depends on the date of issuance of publication and not on the date of orally reading a paper. Genth's paper in the *American Journal of Science* was issued, as all numbers of that Journal are, on the first of the month, that is July 1, 1876. Our library copy of the Proceedings of the Royal Society (London), Vol. 25, has printed on the bottom of the title page, MDCCCLXXVII, that is, 1877. Both your footnote No. 1 on page 376, and Dana's reference to mottramite, give 1876. Moreover, as volume 25 of the Royal Society takes in part of 1877, it could not have been printed in 1876. Even if the complete volume (No. 25) were issued in parts, Roscoe did not read or present his paper until the meeting of June 15, 1876, and in order to have priority, the report of that meeting must have been printed and issued in less than two weeks, that is between June 15 and June 30. If I am in error on this subject, I hope you will correct me.

<sup>1</sup> Published by permission of the Director, U. S. Geological Survey.

<sup>2</sup> Taber, Stephen, and Schaller, W. T., Psittacinite from the Higgins mine, Bisbee, Arizona: *Am. Mineral.* Vol. 15, pp. 575-579, 1930.

<sup>3</sup> Bannister, F. A., The identity of mottramite and psittacinite with cupriferous descloizite: *Mineralog. Mag.*, Vol. 23, pp. 376-386, 1933.



Bannister's reply, in part, follows:

In reply to your question on the priority of mottramite, Roscoe's paper was received May 10, 1876, published and issued in Part No. 172 of Vol. 25 of Proc. Roy. Soc. on the 1st June 1876 but was not read until 15th June 1876. The number of these separate paper-bound parts of Vol. 25 of the Proc. Roy. Soc. now in existence is probably very small. I have confirmed, however, that a separate part No. 172 is held by the Royal Society in Burlington House, Piccadilly London, and I am indebted to the Librarian of that Society for the date of publication I am now sending you. There is no doubt, therefore, that the name mottramite appeared in print a month before psittacinite.

The name mottramite, being published on June 1, 1876, two weeks before Roscoe *read* his paper, thus has a month's priority over psittacinite, published July 1, 1876, as already stated by Bannister,<sup>4</sup> and is the name to be taken. The reasons for discarding other synonymous names are given in the two papers cited.

Such questions of nomenclature may hardly seem worthy of the time consumed in determining priority but the question is important in the preparation of a standard book of reference, as the new edition of Dana's *System of Mineralogy*.

For this mineral, the copper analogue of descloizite, mottramite and not psittacinite, is the correct name.

<sup>4</sup> *Op. cit.*, p. 384.

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#### CAUTION AGAINST THE USE OF BORGSTRÖM'S LIQUIDS<sup>1</sup> WITH LEAD-GLASS PRISMS

A. E. ALEXANDER,

*Spencer Lens Co., Buffalo, New York.*

The writer recently had occasion to use Borgström's high index liquids, and employed a Pulfrich refractometer to determine their indices. It was found that the liquids attacked the lead-glass prisms of the refractometer, forming an insoluble white film that could be removed only by regrinding and repolishing.

To avoid the possibility of damaging valuable instruments, it is suggested that only such refractometers be used with these liquids as are known to be equipped with hard glass prisms. The Pulfrich type, "with variable refraction angle" and a special high index Abbe refractometer made by the Spencer Lens Co., are very well adapted for this kind of work.

<sup>1</sup> Borgström, L. H., Ein Beitrag zur Entwicklung der Immersionsmethode, *Bull. Comm. Geol. Finlande*, No. 87, pp. 58-63, 1929.

## NOTICE TO CRYSTALLOGRAPHERS AND CHEMISTS

In order to check the practical value of Barker's method of crystal identification, complete determinative tables have been compiled for the tetragonal system according to the Barker classification angle and other physical properties.

The authors will gladly attempt to determine any artificial compound which is sent to them, provided the crystals are tetragonal and have been described in the literature.

Please mail the crystal in a small vial, designated by a number so as to withhold its identity. Send to J. D. H. Donnay, Johns Hopkins University, Baltimore, Md., or to J. Mélon, Laboratoire de Minéralogie, Université de Liège, Belgium.

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Dr. R. C. Evans, of Clare College, has been appointed University demonstrator in the department of mineralogy and petrology of the University of Cambridge.

At the anniversary meeting of the Mineralogical Society, London, Sir Thomas Holland was elected president and Sir William H. Bragg and Mr. Arthur Russell were elected vice-presidents.

Dr. John Joly, Professor of geology and mineralogy in Dublin University since 1897 died on December 8 at the age of seventy-six years.

Dr. W. H. Collins, Director of the Geological Survey of Canada, delivered the first series of the Grant Memorial Lectures at Northwestern University, Evanston, Illinois. The topics discussed were: The Economic Future of Northern Canada, Major Correlation Problems of the Great Lakes Region, and The Sudbury Mining field.

The presentation of the Penrose Medal to Dr. Waldemar Lindgren of the department of geology at the Massachusetts Institute of Technology was made on December 29 at the annual dinner of the fellows of the Geological Society of America.

Dr. Henry Stephens Washington, petrologist of the Carnegie Institution of Washington since 1912, died on January 7 at the age of sixty-seven years.

EIGHTEEN specimens of meteorites from a group of meteorite craters at Henbury, Australia, have been received at the Field Museum of Natural History, Chicago, and placed on exhibition in the museum's collection. The museum possesses the world's largest meteorite collection as regards the number of falls represented, specimens from more than two thirds of all known meteorite falls being included.

DR. VICTOR MORITZ GOLDSCHMIDT, professor of mineralogy at Göttingen, has been elected an honorary member of the Mineralogical Society of Great Britain.



## PROCEEDINGS OF SOCIETIES

### PHILADELPHIA MINERALOGICAL SOCIETY

*Academy of Natural Sciences of Philadelphia, December 7, 1933*

A stated meeting was held with Dr. Gillson in the chair, and 51 members and 34 visitors present. Mr. Frankenfield announced that prizes had been awarded to Donald Rudolph, and John W. Christman for their exhibits of minerals at the Commercial Museum Hobby Show. Dr. Gillson appointed the following to the membership committee: Messrs. Toothaker, MacNelly, Fleming, Jr., Knorr, and Moyd. Mr. Biernbaum reported in great detail upon the Society's excursion to the Verdolite Quarry at Easton, which afforded many specimens of asbestos, aragonite, calcite, carnotite?, eastonite, thorianite?, talc, serpentine, and zircon to the 43 members of the party. Mr. Morgan reported finding pectolite, apophyllite, prehnite, chabazite, and aragonite at Paterson.

Professor R. J. Colony addressed the society on "The Source of the Sands of Long Island and the Coast of New Jersey," illustrated by means of lantern slides. It was determined that the migration of the Long Island sands is from east to west, and are but once removed from their source in the New England Upland; they contain magnetite. The migration of the New Jersey sands, which contain ilmenite, is north and south from Long Branch, and they are twice removed from their original source. A rising vote of thanks was tendered to Dr. Colony.

W. H. FLACK, *Secretary*

*Academy of Natural Sciences of Philadelphia, January 4, 1934*

President Gillson presided at a regular meeting in the Lecture Hall of the Academy, to which members of the Institution had been invited. Forty-two members and eighty-one guests were present.

The chair announced the death of Edward R. Gudehus on December 24th. Mr. Gordon introduced an amendment to Article II, Section 3, of the By-laws.

Dr. Benjamin L. Miller, Professor of Geology at Lehigh University addressed the society on "Deciphering the Geologic History of Eastern Pennsylvania—Progress Made and Unsolved Problems." A short history of early geologic effort was described, illustrated by early maps and reports. Unsolved problems concern the location of the volcanoes which deposited the six layers of volcanic ash in the Ordovician, as evidenced by the occurrence of bentonite in the sediments; and the development of the present day topography. The talk was illustrated with maps, diagrams, and lantern slides.

W. H. FLACK, *Secretary*

